APPENDIX B
SAMPLE ROCK BOLT SPECIFICATION

B-1. General. The following specification was written specifically for the NORAD Expansion Project (1970-71) and is specific about both excavation procedures and bolt installation procedures. Other projects will have their own unique requirements which will require modifications to this specification.

B-2. Tensioned Rock Bolts.

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B-3. Applicable Publications. Applicable references are listed in Appendix F.

B-4. Materials.

a. Rock Bolts, Hollow Bar Groutable Type. (See figure B-1.)

(1) Williams US-8-HC-SCS-158 or US-8-SCS-175, hollow-core, high bond, high strength rebar groutable type rock bolt as manufactured by Williams Form Engineering Corporation, Grand Rapids, Michigan, or equal, complete with standard expansion shell head assembly, bearing plate, bevel and flat washers, and hexagonal nut; or the same groutable rebar equipped with shells and accessories listed in paragraph B-4a(2) (a)

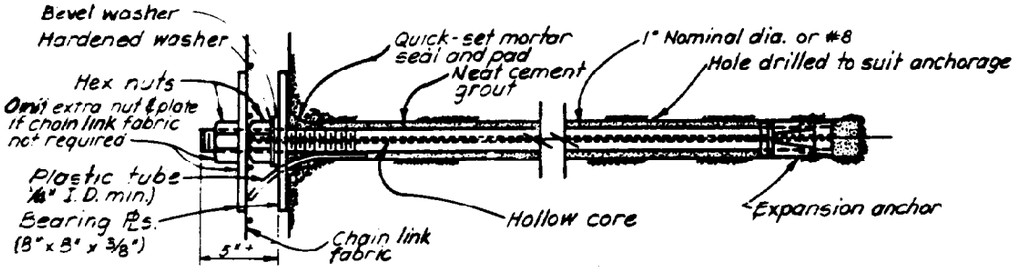


Figure B-1. Grouted rock bolt (with chain link fabric).

and (b). The various lengths required are indicated on the drawings. The use of rock bolt coupling (manufacturer's standard long couplings with hole for grout passage) for splicing rock bolts where required to provide the lengths indicated, will be permitted.

(2) Titan. Nominal 1-inch hollow-core, high bond, high strength groutable deformed rebar conforming to the tensile requirements of ASTM A 615,[25] grade 40. The hollow core shall be 1/4-inch nominal diameter with countersink at ends of rebar. Cross-sectional area of the hollow core and countersink at end of bar shall be equal to that of the Williams rebar specified in B-4a(1). The various lengths required are indicated on the drawings. The use of rock bolt couplings (manufacturer's standard long couplings with hole for grout passage) for splicing rock bolts where required to provide the lengths indicated, will be permitted. Titan rebars are available from Tower Pacific Corporation, 101 Townsend Street, San Francisco, California 94107. The following expansion shell anchorage units are suitable for use with Titan rebars.

(a) D-5 Pattin expansion shell anchorage available from Colorado Fuel and Iron Corporation, P. O. Box 1920, Denver, Colorado, or equal.

(b) K-4 expansion shell anchorage available from Bethlehem Steel Corporation, Lebanon, Pennsylvania, or equal.

Bearing plates, bevel and flat washers, and hexagonal nuts shall be as specified herein.

b. Rock Bolt Deformeter shall consist of rock deformeter assembly available from Williams Form Engineering Corporation, Grand Rapids, Michigan, or equal size, complete, including brass protective cap, grout and vent tubes, 8- by 8- by 3/8-inch-square steel bearing plate, hard steel washer, bevel washer, and hex nut but excluding the dial gage. Deformeter lengths are indicated in the drawings. (See figure B-2.)

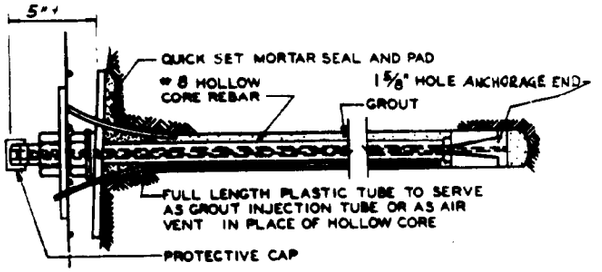


Figure B-2. Rock bolt deformeter.

c. Cement shall conform to Federal Specification SS-C-192g,[7] Type 1, Type II, or Type III, as indicated. The cement shall meet the requirements for low alkali and for control of false set contained therein.

d. Bearing Plates shall be of steel conforming to ASTM A 36,[22] with holes for installation over rock bolts and for accommodating grout and vent tubes, where necessary. Bearing plates shall be 8 inches by 8 inches by 3/8 inch.

e. Hex Nuts shall conform to ASTM A 307,[23] Grade B, heavy-duty.

f. Flat Washers shall conform to ASTM A 325,[24] quenched and tempered to a Rockwell hardness of C 38 to C 45. A quenched and tempered flat washer shall always form the seat for a heavy-duty hex nut.

g. Bevel Washers shall be ASTM A 36[22] steel, circular, standard slope, and minimum diameter to accommodate hardened flat washer above.

h. Thread Lubricant shall be a molybdenum base lubricant, similar and equal to Molykote as manufactured by Alpha Molykote Corporation, Stamford, Connecticut, or Molub-Alloy 298 as manufactured by Imperial Oil and Grease Company, Inc., Los Angeles, California.

i. Grout and Vent Tubes shall be semirigid polyvinyl chloride or polyethylene plastic tubes 3/8-inch OD and 1/4-inch ID, or larger at the contractor's option. Tubes for grouting rock bolt deformeters shall be as supplied by the deformeter manufacturer.

j. Water for mixing mortar and grout shall be fresh and free from injurious amount of oil, salt, acid, alkali, organic matter, or other deleterious substance as determined by Corps of Engineers Specification CRD-C 400.[18]

k. Fluidifier Admixture shall conform to Corps of Engineers Specification CRD-C 566.[19]

l. Fly Ash shall conform to Corps of Engineers Specification CRD-C 262, Type F.[17]

m. Quick-Setting Mortar Mix for packing collar of drill hole and forming base for bearing plates shall be a mixture of Type III portland cement, sand, quick-setting admixture and water, or an approved proprietary quick-setting cement and water that when mixed will produce a quick-setting mortar with the necessary handling properties and of sufficient strength to resist grouting pressures and stressing of rock bolts. (Sika-Plug as manufactured by Sika Chemical Corporation, or

Wil-Kwik-Set manufactured by Williams Form Engineering Corporation will meet these requirements.)

n. Sand for mortar or for grout, if a sanded grout mix is required, shall conform to Federal Specification SS-A-281b,[6] Class 1, except that the gradation shall be as specified herein. Particle shape shall be generally rounded or cubical. The sand shall be well graded from fine to coarse within the following limits:

Sieve Designation (U. S. Standard Square Mesh)	Cumulative Percentage by Weight Passing
No. 8	100
No. 16	95-100
No. 30	60-85
No. 50	20-50
No. 100	10-30
No. 200	0-5

o. Chain Link Fabric shall conform to Federal Specification RR-F-191g,[7] Type I, Grade A, No. 6 (0.1920-inch) steel wire gage, woven into 2-inch diamond mesh. Width of chain link fabric shall be coordinated with the rock bolt and rock anchor installation pattern.

p. Expansion Bolts for supporting chain link fabric from rock at intermediate points shall be suitable commercially available steel bolts with steel expansion shields. Expansion bolts shall be 3/4 inch in diameter and of a length to extend approximately 1 foot into sound rock with enough projection from the rock for the proper application of the fabric. (See figure B-3.)

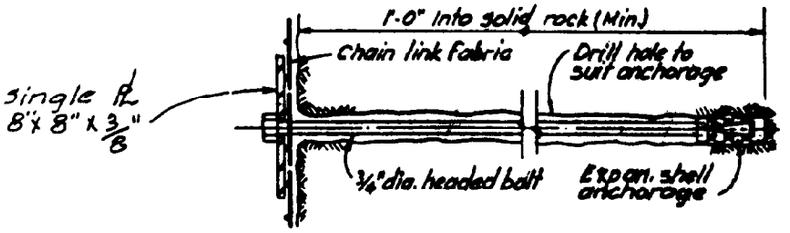


Figure B-3. Supplementary bolts for chain link fabric.

B-5. Certificates. The contractor shall submit certificates of compliance in accordance with SPECIAL PROVISIONS, attesting proof of

compliance with the specifications prior to delivery of the certified material to the project site. Certificates are required for the following materials:

Cement	Washers, flat and bevel
Sand	Nuts
Bearing plates	Chain link fabric

B-6. Planned Installation Pattern for Rock Bolts. The planned installation pattern, sizes, and lengths of the rock bolts are usually indicated on the drawings. Rock conditions encountered as the work progresses may require the actual pattern, sizes, and lengths to vary from the planned installation indicated and the specific location, attitude, size, and length of each rock bolt is subject to adjustment in the field by the contracting officer. In those instances where the rock condition in or behind the burden of the trim cut is such as to be hazardous, prebolting using safety bolts of adequate size and length shall be temporarily installed for the safety of the workman. Safety bolts shall be removed or tension released before shooting the trim cut. Rock bolts, in addition to those shown on the drawings, shall be installed as directed by the contracting officer.

B-7. Test Program. At a time prior to major underground excavation, the contracting officer will designate a test section in rock representative of that to be bolted for conducting a test program designed to provide data for installing rock bolts. The contractor shall notify the contracting officer a minimum of 7 days in advance of starting the test program. A representative of the contractor in charge of installing rock bolts shall witness and actively cooperate in conducting the tests. The installation of the rock bolts for the tests and the tests shall be performed in the presence of a representative of the contracting officer. The test program will consist of:

a. The contractor shall furnish and install a minimum of eight No. 8- by 12-foot-long, hollow-bar, groutable-type rock bolts complete with anchorage shell, bearing plate, bevel and flat washers, and hex nut representative of the units proposed for use in the work.

b. Units shall be installed as specified hereafter to include setting the anchorage, bedding the bearing plate in quick-setting mortar with vent of grout tube in place, adding bevel washers as necessary, flat washer and nut.

c. The contractor will tension the rock bolt within the range of 24,000 pounds to 30,000 pounds, using a direct pull rock bolt tensioning device to verify the anchorage capability and the installation technique.

d. Any bolt installation that fails in the test program shall be dismantled and the cause of failure determined.

e. The error or defect shall be corrected in the subsequent installation and the tests repeated until eight installations are satisfactory.

f. Bolts in the test pattern shall be grouted and will be included for payment as a pattern bolt installation.

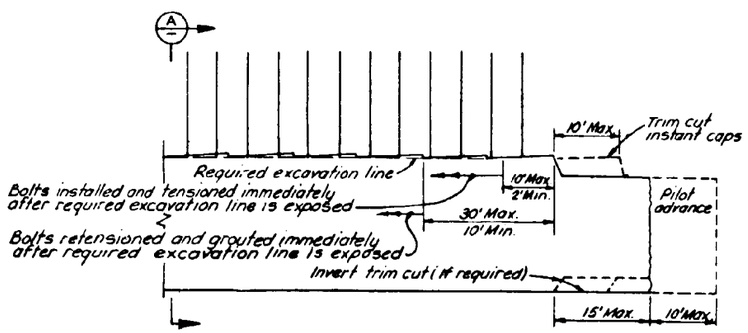
g. The procedures and methods resulting in satisfactory installations shall be used in all bolt installations.

B-8. Drilling Holes. Holes for the installation of rock bolts shall be drilled into the rock to the lengths as shown on the drawings or as directed and to such inclination as will permit bolting generally normal to the rock surface, except when otherwise indicated or as directed. All drilled holes shall be blown clear with compressed air, minimum of 50 psi introduced at the back of the hole, upon completion of drilling. In addition, all horizontal and downwardly inclined holes shall be blown clean immediately before installation of the bolt. Diameter of the drilled hole for expansion shell type rock bolts shall be as recommended by the manufacturer of the expansion shell and this diameter shall not be exceeded in the anchorage area. Holes shall be drilled using properly sharpened bits operated in such manner as to produce straight holes with smooth walls. The diameter of the drilled hole in the anchorage area shall be checked with a hole gage (Ohio Brass Company, Mansfield, Ohio 44902, or equal), and all holes exceeding the recommended diameter by more than 1/16 inch will be considered outside and not acceptable. Such holes shall be redrilled or replaced with a new hole at no additional cost to the Government. The depth of the hole shall be not less than the full length of the bolt plus the anchorage shell.

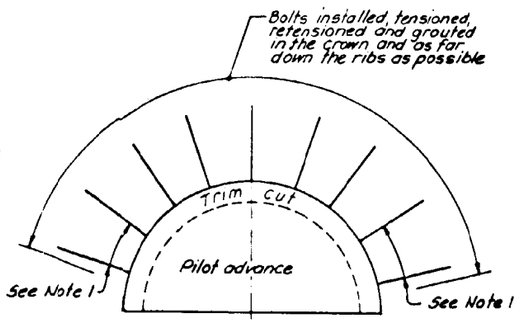
B-9. Installation of Rock Bolts.

a. All rock bolts shall be installed within 8 hours after shooting the round, except in rare instances where it may be necessary for the contracting officer to adjust the 8-hour limitation. (See figure B-4 for additional requirements for bolt installation.)

b. Hollow-Bar Groutable Type of rock bolts shall be installed in accordance with the recommendations of the manufacturer, dependent on the type expansion shell used, subject to the following modifications: (1) set expansion shell using not less than 275 ft-lb of torque or as directed by the contracting officer applied by a calibrated preset



TYPICAL HEADING



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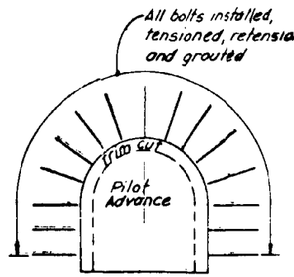
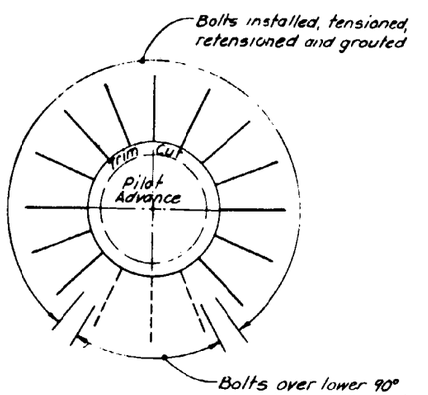


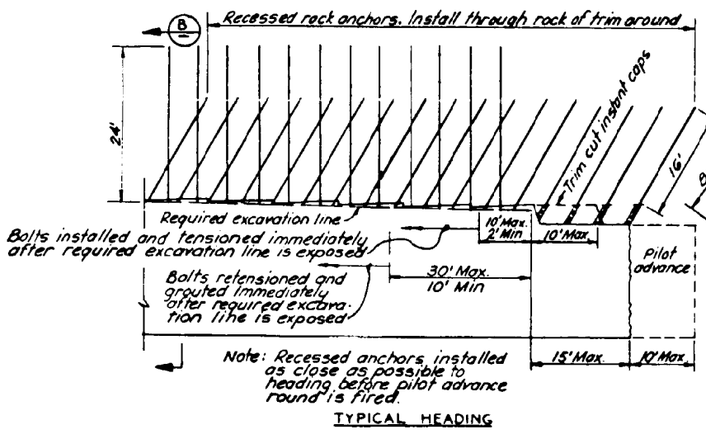
TYPICAL SECTION (A) FULL FACE



TYPICAL SECTION (A) CIRCULAR SECTION
FULL FACE

Rock anchor installation shall follow within 10 feet of trim cut.

TYPICAL BLASTING ADVANCE
NO SCALE



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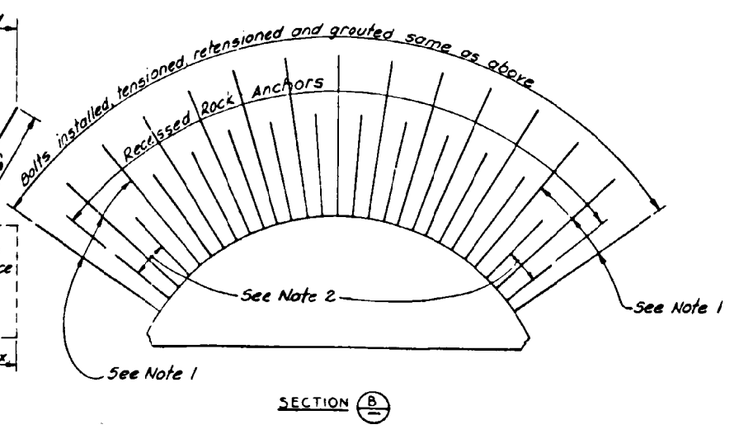

SECTION (B)

NOTES:

1. Where clear space is not sufficient for installing bolts full length, splice shorter lengths. Bolts will be installed as close to future excavation as possible by using 8 ft sections.
2. Install max. length recessed anchors possible (minimum length of 8 feet) where clear space for installing 16 ft long anchors does not exist. These anchors will be considered as 16 foot anchors for payment purposes.
3. Bolts shall be installed and grouted to within the distances indicated to the face before any round is fired in the trim cut or pilot advance

No Scale

Figure B-4. Bolting, blasting and prebolting sequence for crown of power plant chamber.

impact wrench of proven capacity; (2) use bevel washers to limit the maximum thickness of the quick-setting mortar under the bearing plate to less than 2 inches; (3) clean threaded end of rock bolt with thread chaser full length of thread; (4) apply thread lubricant over entire thread and contact surfaces of hex nut and flat and bevel washers; (5) tension the rock bolt between 24,000 pounds minimum and 30,000 pounds maximum loading applied by a direct pull tensioning device; and (6) advance hex nut to contact bearing plate in a tight, solid fit. Any installed bolt that cannot be tensioned to the specified loading shall be replaced by the contractor at no additional cost to the Government. Replacement shall be effected by a new installation.

(1) No additional payment will be made for the replacement installation. After each heading advance, the bolts in that portion of the planned installation pattern as indicated on the drawings shall be retensioned and grouted, as specified hereafter prior to shooting the next round. Bolts shall be retensioned within the range specified herein for the original installation.

(2) If any rock bolt anchorage fails to withstand a retension load of 24,000 pounds, the contracting officer will indicate either (a) grout the bolt in place, (b) add a complete new rock bolt installation, or (c) install a perforated sleeve type rock anchor. Payment for (b) and (c) above will be made based on the installation indicated. Direct pull rock bolt tensioning devices, ELBROC, Mark IX (will require a factory modification to accommodate the 5-inch plus projection) are available from Soiltest, Inc., 2205 Lee Street, Evanston, Illinois 60202. Commerical center pull hydraulic jacks, of the required capacity, modified to provide the required operation will be permitted, subject to the approval of the contracting officer.

(3) Each direct pull rock bolt tensioning device, furnished by the contractor, shall be individually identified to enable the Government to establish and maintain a record calibration schedule verifying the accuracy of the output of each unit. Each unit will be checked by the Government against a load cell at least once in every 7-day period (time to check a unit will average 2 hours). The use of unchecked units will not be permitted. The contractor shall furnish individually identified direct pull rock bolt tensioning devices in sufficient number to permit the Government to accurately verify the output of each unit without disrupting the scheduled rock bolt installation operation. Defective or unreliable units shall either be repaired to indicate a satisfactory operation or replaced. Grout or vent tubes shall be installed as indicated on the drawings.

B-10. Installation of Rock Bolt Deformeters. Rock bolt deformeters

shall be installed at the locations indicated on the drawings and as specified above for installation of hollow bar groutable type rock bolts with the addition of a full length plastic tube to serve as a grout injection tube or as an air vent in place of the blocked hollow core. Tensioning, retensioning, and grouting will be required. Grout injection of deformeter inclined upward, when viewed from the collar of the hole, shall be through the short tube. When inclined downward, grout injection shall be through the long tube. Tubes shall be color coded to differentiate between short and long tubes. Time of grouting of rock bolt deformeters will be the same as for pattern bolts in the same area unless the contracting officer specifies certain ones to be left ungrouted. (Installation and grouting of solid bar rock bolts would be identical to installation and grouting of rock bolt deformeters.)

B-11. Portland Cement Grouting of Rock Bolts and Deformeters.

a. General. Rock bolts and deformeters shall be pressure grouted as specified herein. The annular space around each rock bolt, tie bolt, or deformeter shall be filled by pumping grout through the injection tube at pressures not to exceed 25 psi measured at the collar of the hole. The annular space will be considered grouted when there is a full flow return of grout through the vent. For up bolts and approximately horizontal bolts, the short plastic tube sealed in the collar of the hole shall be used as the grout injection tube and the hollow core of the bolt used as a vent tube. For units inclined downward more than 3 degrees from the horizontal, the injection and venting processes shall be reversed. A grout tube adapter available from Williams Form Engineering Corporation, Grand Rapids, Michigan, or equal, shall be used when grout is injected through the hollow core.

b. Grouting.

(1) Grout mixing and pumping equipment. All equipment used for mixing and injecting grout shall be of a type and capacity approved by the contracting officer and shall be maintained in first class operation condition at all times. The selection of equipment and the determination of its suitability to the work shall be based upon a maximum grouting pressure of 100 psi at the pump. The minimum grouting equipment to be furnished shall include the following:

(a) One grout pump capable of delivering grout at the pressure required by the grouting procedures. The grout pump shall be similar and equal to a "Moyno" double helical screw type pump as manufactured by Robbins and Myers, Inc., of Springfield, Ohio. The intake to the grout pump shall consist of an open hopper to allow visual observation of the grout at the intake. The hopper shall be fitted with a No. 8

screen through which all the grout must pass. An accurate pressure gage shall be provided at the discharge of the pump.

(b) One mechanically driven paddle-type grout mixer of standard make capable of effectively mixing and stirring the type of grout required by these grouting operations. The mixer shall be equipped with a gravity feed water measuring device mounted over the mixer with a discharge tube and control valve for discharging the specified quantities of water to the mixer. The water container shall be made with clear plastic and shall have a capacity suitable for the size of batch. The plastic container shall be calibrated to read to the nearest five-hundredth (0.05) cubic foot. The calibrated increments shall be imprinted on the plastic container wall so that the column of water can be read by eye. A readily adjustable overflow pipe shall be provided in the plastic container to positively regulate the amount of water available for discharge into each batch.

(c) A mechanically agitated sump, so designed as to effectively stir and hold in suspension all solid matter in the grout. If grout mixer and grout pump are suitably arranged and operated so as to preclude need for a sump, it may be omitted if specifically approved.

(d) An approved "gun" or arrangement of valves shall be provided in the grout lines not more than 12 feet from the nozzle end to be attached to the injection tube for each individual bolt. A return line of at least 3/4-inch ID shall be provided from this point to the mixer, or sump if used, and grout shall be continually circulated through the return line whenever grout is in the pump and lines, except when actually injecting grout into each individual bolt hole. Supply line to the "gun" or arrangement of valves shall be at least 3/4-inch ID and line for connection to each individual bolt shall be at least 1/2-inch ID and not over 12 feet long.

(e) Valves, pressure gages, pressure hose, small tools, and accessories as may be necessary to provide a continuous supply of grout and accurate pressure control will be required.

(f) The contractor shall keep on hand at the work site a supply of extra hoses, tubes, accessories, and small tools as required to minimize work stoppages due to need for replacement items during grouting operations.

(2) Grout mixture. The grout mixture shall consist of the following materials in these proportions:

Portland cement, Type III	(2 sacks)	188 lb
Fly ash	(1 sack)	75 lb
Interplast-C or equal	(1 percent cement + fly ash)	2.6 lb
Water		(see note)

Note: Water shall be in such quantity that grout will have an efflux time of 20 seconds or more when tested in accordance with Corps of Engineers Test Method CRD-C 79-58.[15]

(3) Mixing and handling. All grout shall be mixed in the specified type mixer. Dry materials charged into the mixer shall be measured by volume except that the admixture for each batch shall be furnished to the mixer in individual containers of preweighed material. Water shall be measured by the specified measuring device on the mixer. All mixing, pumping, and packing operations shall be carefully coordinated so that no delay occurs in the process. Any grout which commences to set or indicates an appreciable change in consistency before grouting operations are complete shall be completely removed from mixer, sump, pump, and lines and discarded as directed.

(4) Grouting of rock bolts. All grout pipes, tubes, and fittings shall be clean and free from dirt, grease, hardened grout, or other contamination before grouting is commenced for any bolt. All wash water and diluted grout shall be flushed from all lines and wasted before commencing operations. The grout line shall be attached to the grout injection tube for the individual bolt with suitable fittings such that leakage is entirely prevented. The grout shall be injected at a rigidly controlled pressure, as approved. Equipment which cannot maintain a uniform pressure as directed shall be removed and replaced with suitable equipment. Care shall be taken to avoid premature clogging of pipes or tubes and any pipe or tube that becomes clogged or obstructed, before completion of grouting operations, shall be removed, cleaned, and replaced in an approved manner at no cost to the Government. The grouting of any bolt shall not be considered complete until the grout flows from the vent in a steady stream. The vent tube shall be plugged and the grout injection tube sealed, with pressure maintained on the injection tube. In any case the hole shall be left completely filled. All actual grout injection shall take place in the presence of a representative of the contracting officer.

(5) Leaks and grout loss. If during grouting of any bolt hole grout leaks to the surface of the rock through an open seam or other void and visibly indicates appreciable loss of grout, grouting operations shall be temporarily suspended on this bolt hole and the seam calked with quick-setting mortar or as otherwise approved. If during

grouting of any bolt hole the hole accepts more grout than required to fill the nominal volume of the annular space in the hole, and if no grout leakage is visible at the surface, grouting operations shall be temporarily suspended on this bolt hole. Not earlier than 1 hour and not later than 2 hours after suspension of grouting on the bolt hole, the grout lines shall be reconnected and grouting of the bolt hole completed. If leakage still continues, grouting shall be continued until termination by the contracting officer. A sanded mix may be required if excess leakage occurs.

B-12. Chain Link Fabric Rock Support.

a. General. Chain link fabric shall be installed where indicated on the drawings or directed by the contracting officer as a secondary support of rock. Installation shall be made following grouting of rock bolts and final scaling, or earlier if directed by the contracting officer.

b. Installation. Installation shall be as shown on the drawings. Fabric shall be lapped at the rock bolt a minimum of three mesh openings and shall be supported from rock bolts. At intermediate points, the fabric shall be supported with 3/4-inch steel expansion bolts installed in holes drilled approximately 1 foot into solid rock where directed. The fabric is not to be lapped at intermediate points. Holes shall be drilled into rock to such depth as to allow the bolt to protrude only far enough beyond the rock surface for proper application of the fabric.

B-13. Measurement and Payment.

a. General. The contract prices for the various items under this section shall constitute full compensation for furnishing all materials, labor, tools, equipment, and incidentals necessary to accomplish the work herein, including cleanup of the area and disposal of waste water and grout.

b. Rock Bolts, hollow bar groutable type, will be measured by the unit each for the various lengths involved and will be paid for at the contract unit price each for "Rock Bolts, Hollow Bar Groutable Type" to include drilling the hole, installing the bolt, initial tensioning, final tensioning, and pressure grouting. Additional grout as required under paragraph "Leaks and Grout Loss" will be measured by the sack of portland cement used and will be paid for at the contract unit price per sack for "Portland Cement Grout Loss." The quantity for "Portland Cement Grout Loss" indicated in the Unit Price Schedule is estimated and the Government reserves the right to order any increase or decrease

in the actual number of sacks of portland cement required without any restriction percentagewise from the estimated quantity stated in the contract without any recourse by the contractor to demand any adjustment in the contract unit price or to claim loss of anticipated profit by reason of such change.

c. Chain Link Fabric will be measured by the square foot, computed from the length and width of the rock surface covered, computed in accordance with the design configuration indicated on the drawings, excluding any corner chamfer, and no allowance for laps, and will be paid for at the contract unit price per square foot for chain link fabric.

d. Expansion Bolts Supporting Chain Link Fabric will be measured by the unit each and will be paid for at the contract unit price each for "Expansion Bolts Supporting Chain Link Fabric."

e. Bearing Plates for Supporting Chain Link Fabric will be measured by the unit each and will be paid for at the contract unit price each for "Bearing Plates - Chain Link Fabric Support," such payment to include supplementary hex nuts as required.

f. Rock Bolt Deformeters will be measured by the unit each, of the various lengths involved, complete in place, including pressure grouting, and will be paid for at the contract unit price each for "Rock Bolt Deformeters."